THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

JUNE, 1957

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VOLUME 30 NUMBER 6

THE MOND NICKEL COMPANY LTD • THAMES HOUSE, MILLBANK, LONDON, S.W.1
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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Vacuum Melting of Metals and Alloys

W. SCHEIBE: 'Some Examples of the Use of High-Vacuum Techniques in Metallurgy.'
Zeitsch. f. Metallkunde, 1957, vol. 48, Mar., pp. 91–100.

Review of some of the results which have been obtained by high-vacuum technique in the production and processing of metals and alloys. The improvement in properties obtainable by such methods is demonstrated by reference to results which have been reported in the literature, supplemented by the author's own experiments. Particular attention is directed to the beneficial effects, on mechanical and physical properties, obtainable by this method. The supporting data include published values for vacuum-melted and/or -processed steels and alloys of high nickel content.

Powder-Metallurgy Symposium

IRON AND STEEL INST.: 'Symposium on Powder Metallurgy, 1954.'
I.S.I. Special Report No. 58; 390 pp.
Published by the Institute, 1956.

The symposium included a number of review papers, presenting the position of powder-metallurgy development at the date at which the symposium was held, together with other contributions in which particular emphasis was placed on progress in research and development which had taken place since 1947, the date of the earlier symposium arranged by the Institute. As in 1947, the Institute of Metals co-operated with the Iron and Steel Institute in obtaining the contributions offered.

The papers are arranged in sections dealing, respectively, with

- Manufacture, Properties and Testing of Powders
- Principles and Control of Compacting and Sintering
- Manufacture and Properties of Structural Engineering Components made by Powder-Metallurgical Methods
- Powder Metallurgy of High-Melting-Point Materials

More than 50 papers are contained in this volume, together with the discussions to which they gave rise. Several of the contributions deal with the application of powder metallurgy to nickel-containing materials, e.g., permanent-magnet alloys, filters, engineering components, and gas-turbine blading.

Yield Effect in Single Crystals

See abstract on p. 85.

NICKEL

Treatment of Low-Grade Nickel Ores

J. E. SHELTON: 'Beneficiation Studies of Nickeliferous Ores from the Shamrock Mine, Jackson County, Oregon, and The Congress Mine, Ferry County, Washington.'
U.S. Bur. Mines, Report of Investigations 5261, Oct. 1956; 8 pp.

Report of flotation tests on samples of two low-grade nickeliferous ores. In one of them the nickel content was 1·2 per cent., occurring chiefly as millerite: in the other, which was chiefly pentlandite, nickeliferous pyrrhotite and chalcopyrite, the metal content was nickel 2·20, copper 0·78, per cent.

Nickel and Nickel Alloys: Literature Review

R. M. FULLER: 'Nickel, including High-Nickel Alloys.'
Reprint from *Industrial and Engineering Chemistry*, September 1956, Pt. II: see abstract in *Nickel Bulletin* 1956, vol. 29, No. 12, p. 205.
Issued by INTERNATIONAL NICKEL CO., INC.

The review gives a summary of the literature which became available in 1955, together with some earlier items which had not been included in previous reviews. The scope covered is the alloys containing more than 40 per cent. of nickel or substantial quantities of cobalt.

Cast Nickel: Data Sheet

INTERNATIONAL NICKEL CO., INC.: 'Engineering Properties of Cast Nickel.'
Published 1956; 8 pp.

Information is given on compositions suitable for three grades of cast nickel: regular type, graphitic nickel, and a wear-resisting grade containing 6 per cent. of silicon. Physical constants are tabulated for the three types of material and details are given of thermal-expansion characteristics, hot hardness, resistance to galling and wear (with particular reference to the usefulness of the graphitic and high-silicon types), and mechanical properties. Recommendations are made on machining, on welding and brazing technique, and on finishing procedures.

Chemisorption of Gases on Nickel

P. M. GUNDRY and F. C. TOMPKINS: 'Chemisorption of Gases on Nickel Films.'

Trans. Faraday Soc., 1957, vol. 52, Feb., pp. 218–28.

In an earlier paper the authors reported a study of the kinetics of chemisorption of hydrogen and carbon monoxide by nickel films at low temperatures (*ibid.*, 1956, vol. 52, p. 1609; *Nickel Bulletin*, 1957, vol. 30, No. 2, p. 30). The second part of the investigation covered a study of the equilibrium properties of the hydrogen+nickel and carbon monoxide+nickel systems. It was found that the slow sorption observed comprises two processes: a low-temperature one which is a surface phenomenon and a high-temperature one which comprises, at least in part, absorption into the bulk of the metal film. The ratio of the amount of carbon monoxide adsorbed to that of hydrogen, under comparable conditions, is about 1·5, a value similar to that found for iron films.

Nitriding of Nickel

J. J. TRILLAT: 'Electronic Diffraction Study of the Nitriding of Nickel.'

Comptes Rendus, 1957, vol. 244, Jan. 28, pp. 596–8.

Thin films of nickel were subjected, at various temperatures, to the action of ammonia gas. At low temperatures (150°–200°C.) nitrogen enters the face-centred-cubic lattice and dilates it, but there is no indication of formation of a compound. At higher temperatures, however, the structure transforms to a compact hexagonal type and formation of a nitride is indicated.

Growth and Oxidation of Thermally Deposited Nickel Films

See abstract on p. 89.

Magnetostrictive Properties of Nickel-containing Materials

E. M. WISE: 'Magnetostriction: A New Design Tool.'

Reprint of paper from *Product Engineering*, Jan. 1957; see abstract in *Nickel Bulletin*, 1957, vol. 30, No. 5, p. 68.

Issued by INTERNATIONAL NICKEL CO., INC.

Yield Effect in Nickel Single Crystals

P. HAASEN and A. KELLY: 'A Yield Phenomenon in Face-Centred-Cubic Single Crystals.'

Acta Metallurgica, 1957, vol. 5, Apr., pp. 192–9.

Various investigators have reported the existence of a small but measurable yield point in the stress-strain curves of single crystals of metals re-strained after prior deformation and ageing. The authors found this effect in single crystals of nickel and aluminium deformed at 20°, 78° and 90°K. (−253°, −195° and −183°C.) and at room temperature. It is pointed out that the phenomenon appears to be general in single crystals of pure face-centred-cubic metals deformed at low temperatures. Possible explanations are discussed.

Sintered Nickel Accumulator Plates

P. L. BOURGAULT: 'Nickel-Cadmium Batteries. II. Impregnation of Positive Plates by Thermal Decomposition of Aqueous Nickel Nitrate.'

Canad. Jnl. Technology, 1957, vol. 34, Mar., pp. 495–502.

This paper is a sequel to that published *ibid.*, 1956, vol. 34, pp. 95–103; see abstract in *Nickel Bulletin*, 1956, vol. 29, No. 12, pp. 205–6.

The methods for preparation of sintered nickel accumulator plates described in the earlier paper, and by FLEISCHER (*Jnl. Electrochemical Soc.*, 1948, vol. 94, pp. 289–99; *Nickel Bulletin*, 1949, vol. 22, Nos. 1–2, p. 6) are long and complex. The modified procedure, fully described in the present paper, reduces the number of steps involved and replaces the polarization step essential in the earlier method by a thermal decomposition and chemical conversion.

According to the new technique, the sintered-nickel plaque is first immersed in aqueous nickel nitrate, and the nitrate in the pores is decomposed, at high temperatures, to an intermediate which, in caustic solutions, converts rapidly to nickel hydroxide. A detailed study has been made of the influence of time and temperature of immersion, of the conditions of thermal decomposition, and of the surrounding atmosphere. The results have led to a cycle by which it is possible, in five steps, to produce positive sintered plates containing the same amount of active material as is found in plates formed by the commercial sixteen-step method. Data on the electrical behaviour of the plates, presented in the paper, indicate that their capacity is as high as that of plates prepared by standard cycles, involving, *inter alia*, four impregnations.

Doubly-impregnated plates, made by a modification of the new method, give strong plates which have much higher capacity than standard commercial types. The electrical output of such doubly impregnated plates exceeds that of commercial plates, even up to current densities of 1 amp./sq. in.

The authors include a preliminary discussion of the mechanism of the impregnation process.

Powder-Metallurgy Symposium

See abstract on p. 84.

Nickel-containing Catalysts

A. M. RUBINSCHTEIN, *et al.*: 'Activity of Oxides, Sulphides and Selenides of Nickel, Chromium and Zinc in Reactions.'

Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk, 1956, pp. 596–603: see also English translation in *Bull. Acad. Sciences, U.S.S.R., Div. Chemical Sciences*, 1956, pp. 595–601.

Abstract in *Chemical Abstracts*, 1957, vol. 51, p. 1871.

Porosity in Nickel Welds

D. R. MILNER: 'Porosity in Nickel Welded by the Argon-Arc Process.'

Brit. Welding Jnl., 1956, vol. 3, Nov., pp. 542–5.

Welds made in nickel and high-nickel alloys by the argon-arc process are liable to show porosity. Two methods have been suggested for prevention of this defect: (1) addition of hydrogen to the arc shroud, and (2) addition of titanium to the parent plate and, in larger proportions, to the filler rods. This paper reports a study of the subject, covering investigation of the reactions involved in both the remedial methods proposed. The observations made led to the following conclusions:

The porosity found in the welds is due to the absorption of oxygen, which then reacts with the carbon impurity in the parent metal, forming carbon monoxide. Under laboratory conditions, the oxygen originates from the exposure of the underside of the weld to the air: the argon shroud was found to give adequate protection to the upper surface of the weld.

The evidence obtained suggests that the formation of porosity takes place in two stages: (1) the oxygen from the welding atmosphere is absorbed at the weld surface, forming nickel oxide; (2) the oxide, under the stirring action of the arc, is mixed into the weld pool, and there reacts with the carbon, to form carbon monoxide.

The author's results confirmed the effectiveness of hydrogen additions to the argon shroud, as a means of eliminating porosity. It is concluded that some of the hydrogen is absorbed at the upper surface of the weld and re-liberated at the underside, where it reacts with oxygen, to form steam, thus preventing the entry of oxygen, in the form of nickel oxide, into the weld pool.

ELECTRODEPOSITION AND OTHER COATING METHODS

Electrodeposited Metal Coatings: Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Properties, Tests and Performance of Electrodeposited Metallic Coatings.'

A.S.T.M. Special Tech. Publn. No. 197, 1957; 129 pp.

Containing papers and discussions presented at meetings held in Buffalo, N.Y., February, 1956, and at Los Angeles, Calif., September 1956.

W. L. PINNER: 'Introductory Remarks', p. 1.

Note on the activities of A.S.T.M. Committee B-8 on Electrodeposited Metallic Coatings, which sponsored this symposium. Emphasis on the wide range of work completed and in progress.

W. BLUM: 'History of A.S.T.M. Committee B-8', pp. 3–6.

Review of the evolution of this Committee from other groups concerned with corrosion of metals and alloys. Short survey of work, from 1927 onwards, sponsored by various committees of the Society and culminating in the formation, in 1941, of the B-8 committee, which maintains close association with other groups of the American Society for Testing Materials and with the American Electroplaters' Society.

C. H. SAMPLE: 'The Corrosion Behaviour and Protective Value of Copper/Nickel/Chromium and Nickel/Chromium Coatings on Steel', pp. 7–21; disc. pp. 21–4.

Reprint of this paper issued by INTERNATIONAL NICKEL CO., INC., 1957.

This report comprises a summary of three series of tests carried out under the guidance of Committee B-8. Brief notes are given on the nature of the specimens, the conditions of exposure and the principal conclusions drawn from observations made by individuals appointed by the committee to assign ratings under agreed schedules. (For full details of specimens, mode of preparation and exposure, etc., attention is directed to earlier reports published in the A.S.T.M. Proceedings.) Notes on the respective series of tests are given below:

Programme 1, started immediately after World War II, covered a series of atmospheric tests which had for its primary objective evaluation of the relative durability of decorative copper/nickel/chromium and nickel/chromium coatings, on steel of bumper-bar grade. Specimens were exposed in six different atmospheres, and an additional set of identical samples was subjected to the salt-spray (fog) test. The results of these tests (after about three years) led to the following conclusions:

(1) The type of atmosphere had a very large effect on rate of deterioration.

(2) The thickness of the nickel coating (with or without copper underlay) was the principal factor determining the atmospheric weathering characteristics, in all atmospheres.

(3) The copper undercoats added little to the protective value of the composite coating and the slight benefit conferred was important only in the early stages of deterioration or in the mildest corrosive atmospheres. Buffing of the copper undercoat may have been slightly beneficial, but the effect was minor and not persistent.

(4) Application of the nickel coating in two steps, with the first layer buffed, or annealed and buffed, was highly beneficial in a seacoast environment, but was of no benefit in an industrial atmosphere. The type of nickel plating (dull, semi-bright, or bright) exerted no important influence on the life of the coatings.

(5) Identical simple and composite coatings behaved similarly, whether plated on a high-carbon steel base or on the low-alloy high-tensile steel used.

The criticism with regard to copper undercoats was challenged by some electroplaters, on the ground

that the poor results might be due to inadequate thickness of copper.

Programme 2 was therefore initiated, to provide for supplementary comparative tests of nickel/chromium-plated and copper/nickel/chromium-plated specimens. These tests were made in atmospheres representative of marine and marine-industrial areas. The results were inconclusive, not being in agreement with those derived from Programme 1.

Programme 3 was designed to clarify the position, by finding some explanation for the discrepancies. Particular attention was given to precise and uniform preparation of the specimens, and some modifications were introduced into the system of inspection, to ensure greater discrimination in rating the behaviour of the coatings. (Comments on rating methods are included in the present report.) The effects of intermittent cleaning of the specimens was also studied, with a view to simulating conditions of service of automobiles. The exposure sites were again marine and industrial.

After just over a year the Committee considered the following conclusions to be justified:

'1. The effect of the thickness of cyanide-copper flash deposited under the acid-copper coating appears to be slight, but where a difference exists it is in favour of the heavier flash coating. The results, however, would not appear to account for the marked differences in the effect of thickness of copper flash observed when comparing the results of Programme 1 with those of Programme 2.

'2. In a seacoast atmosphere, where 'protective value', as opposed to 'surface pitting', is the principal factor revealed, Watts-nickel underlay coatings appear to be markedly superior to all types of bright nickel coatings and to coatings of the composite copper/nickel type. In industrial atmospheres no differences warranting such conclusion became apparent.

'3. Except for some scattered results, intermittent cleaning appears to have little influence on progress of deterioration.

'4. Within the limitations of time of exposure, data from the three sites indicate that the purely marine atmosphere was very much more destructive than the industrial and marine-industrial types.'

The author of this composite report draws attention to the consistent superiority (in the Programme 1 tests) of the specimens carrying all-nickel underlays deposited in two layers. Although in the report of those tests it was concluded that the superiority of such coatings was clearly demonstrated only in marine atmospheres, further analysis of the data indicates that the double-nickel type of underlay gives better protection also in rural atmospheres and, to a slighter extent, in industrial areas. An explanation for the varying degrees of improvement apparent in different atmospheres is suggested.

In addition to the conclusions of the Committee, summarized above, the author makes the following comments, based on his own observations and analysis of the test data:

'1. When boldly exposed to the weather in industrial, marine, or rural locations, decorative chromium coatings, with an underlay of buffed Watts nickel applied directly to steel, maintain an acceptable appearance longer than do combination copper/nickel/chromium coatings of the same total thickness.

'2. The acceptable decorative life of copper/nickel/chromium coatings exposed to the weather decreases as the ratio of the thickness of copper to that of nickel increases.

'3. The nickel/chromium coatings in which the nickel was applied in two layers, with the first layer annealed and buffed or only buffed, provided, in marine and rural atmospheres, protective value that was markedly superior to that of the single-nickel-layer coatings of the same total thickness. Improved protective value of these coatings was also evident in the industrial environments, but to a much lesser extent than in the marine and rural locations.

'4. The so-called 'Standard Salt-Spray Test' will not reveal the differences in the protective value of copper/nickel/chromium *vs.* nickel/chromium coatings on steel such as are made evident by comparative atmospheric exposure tests in industrial, marine, and rural locations.'

G. B. BOWMAN: 'Evaluation of Methods available for Measurement of Surface Lustre of Electroplated Coatings', pp. 25–36; disc., p. 36.

Report of examination of typical coatings, by instruments determining surface roughness or optical characteristics. The relative usefulness of various types of measurement is evaluated, and reproducibility data are provided. The difficulty of examining curved surfaces by optical methods is emphasized, and it is concluded that no instrument yet developed is capable of making exact measurements in all cases.

S. SPRING and MEMBERS OF SECTION K OF SUB-COMMITTEE IV OF A.S.T.M. COMMITTEE B-8: 'Recommended Practice for Cleaning prior to Electroplating.'

A list is given of the various types of soil liable to occur on parts which are to be electroplated, and some practical recommendations are made with regard to avoidance of excessive or unnecessary soiling. The factors requiring consideration in cleaning are then reviewed (the nature and condition of the metal to be cleaned; selection and maintenance of the cleaning medium; rinsing procedure, including selection of water, design of rinsing equipment and operating technique; criteria of metal cleanliness). The next section deals with pre-cleaning, or solvent cleaning, with discussion of chlorinated and emulsifiable solvents, solvent-emulsion cleaners and alkaline-spray cleaning. Safety precautions, as well as technical aspects, are considered. Intermediate or alkaline cleaning practice is discussed (soak, spray and barrel methods of operation) and some notes are added on factors which have a major influence on good cleaning (choice and concentration of solution,

temperature of working, duration of treatment, agitation). In considering final electro-cleaning, recommendations are made with regard to conditions for cathodic, anodic and periodic-reverse treatments, and factors affecting selection of electro-cleaning media for specific purposes are reviewed. A brief note is added on acid treatment applied immediately before surface conditioning, and on the effect of conditioning on the appearance of the plating subsequently deposited. For fuller information on this and other aspects of the preparation of metallic surfaces for electroplating, attention is directed to Recommended Practice Schedules incorporated in the A.S.T.M. Book of Standards.

C. H. SAMPLE, A. MENDIZZA and R. B. TEEL: 'A Comparison of the Corrosion Behaviour and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel', pp. 49–64; disc., pp. 64–5.

Evaluation on the basis of results of tests of varying duration made in a wide variety of environment, and of accelerated tests. Among the main conclusions are the following:

The type of environment has a major influence on the protective value of zinc or cadmium coatings; both types fail more rapidly in industrial atmospheres than in marine or rural locations. In some industrial locations zinc coatings last significantly longer than cadmium coatings of the same thickness; in marine and rural locations the reverse is the case. In salt-spray (fog) tests cadmium coatings gave longer protection than zinc, but in fresh-water spray zinc was superior. The results confirmed the failure of salt-spray tests to correlate with behaviour under atmospheric exposure.

A. L. ALEXANDER: 'Evaluation of Phosphate Coatings over Electrodeposited Zinc', pp. 66–90.

Report of behaviour of phosphate-coated zinc-plated specimens exposed to salt-spray and humidity tests and to various types of atmosphere.

R. E. HARR: 'Evaluation of Testing Methods for Supplementary Coatings. A Progress Report of Work under Way', pp. 91–5; disc., pp. 95–6.

Report of progress in development of improved specification tests for evaluation of 'supplementary' (non-metallic) coatings. Presentation of results of preliminary tests of coated specimens exposed to various environments. The types of coating covered by the report are phosphate coatings on zinc, chromate coatings on cadmium, and chromate coatings on zinc. There is a short discussion of accelerated tests which are of interest in evaluation of such coatings.

A. L. DuROSE: 'Atmospheric Exposure of Electroplated Lead Coatings on Steel', pp. 97–104; disc., pp. 105–6.

Report of tests made in connexion with the possible requirement for use of lead in place of zinc during wartime shortage of the latter material. The coatings showed wide variation in behaviour, according to the nature of the atmosphere in which they were exposed.

A. MENDIZZA: 'The Standard Salt-Spray Test: Is it a Valid Acceptance Test?' pp. 107–17; disc., pp. 118–29.

This is the paper and discussion reprinted in *Plating*, February 1957, and abstracted in *Nickel Bulletin*, 1957, vol. 30, No. 5, pp. 73–4.

Automatic Electroplating Plant

R. J. HORROCKS: 'Design and Construction of a New Plating Department.'
Metal Finishing, 1957, vol. 55, Feb., pp. 56–60.

The article describes the newly erected plating department of Eclipse-Pioneer Division, Bendix Aviation Corporation, which includes a number of special features designed to permit operation of a very wide variety of plating and related processes.

Electrodeposition of Nickel on Zirconium

Y. B. KATAYAMA: 'Electroplating on Zirconium.' *U.S. Atomic Energy Commission Report HW-34496*, Jan. 18, 1955; 4 pp.

An electrodeposited insert of nickel or copper has been proposed as a sandwich layer for the bonding of zirconium to other metals, for which purpose good adhesion between the zirconium and the electrodeposited coating is essential.

The following cycle has been developed in the laboratories of the General Electric Company, U.S.A.:

1. Degrease in acetone.
*2. Etch for one minute in an aqueous solution containing NH_4F 18 g/L and HF 6 cc./L.
3. Rinse.
*4. Etch for $\frac{1}{4}$ to $\frac{1}{2}$ minute in an aqueous solution containing HF 20 cc./L.
5. Rinse.
6. Electroplate.
7. Rinse.
8. Dry.

* Both etchants are used at room temperature. The time of immersion should be carefully controlled, to prevent excessive penetration of the metal.

Protection of Molybdenum by Electrodeposited Coatings

R. J. RUNCH: 'Metallographic Study of Electroplated Coatings of Chromium and Nickel on Molybdenum.' *Jnl. Electrochemical Soc.*, 1957, vol. 104, Feb., pp. 74–9.

Study of methods of protecting molybdenum from high-temperature oxidation has indicated that:

(*a*) *Electrodeposited chromium* is of particular interest, because chromium is soluble in molybdenum and does not form brittle intermetallic compounds, and because it has a low thermal-expansion coefficient, similar to that of molybdenum.

(*b*) *Electrodeposited nickel* holds promise because it has relatively good resistance to oxidation by atmospheres containing MoO_3, and on account of its ductility. Nickel, however, forms brittle intermetallic compounds with molybdenum, and also has a relatively high thermal coefficient of expansion.

Chromium+nickel-plated specimens have proved, in some cases, to give good protection to molybdenum in air at 900°C., but the results have not been consistent, and the metallographic examination of coatings reported in this paper was carried out to ascertain the reason for the uncertain behaviour.

Examination of single-layer and various forms of multiple-layer coatings, including typical deposits which had given adequate protection or had been ineffective, led to the following conclusions:

'Electroplated coatings of either chromium or nickel afford considerable protection to molybdenum at high temperatures, but both types of coating have shortcomings and, if used singly, are not likely to produce consistent results.

'The principal problems with electroplated chromium are its tendency to crack, and the relatively poor throwing power of the plating solutions. Chromium forms a good bond with molybdenum and the interfacial alloy between these two metals appears to have good oxidation-resistance and probably has good ductility. Electroplated chromium may be superior to nickel for protecting molybdenum: low-contraction chromium is probably superior to hard chromium. In contrast, electrodeposited nickel apparently did not form cracks, and it effectively bridged flaws in the basis metal, but the problem of obtaining good adhesion of nickel to molybdenum appeared to be more formidable than with chromium.

'The undesirable features of electrodeposited chromium (cracking and poor coverage) may be to some extent overcome by covering it with a layer of nickel. The nickel layer appears to be capable of covering many of the faults which extend through the chromium plate and also of preventing the chromium from cracking when heated. Nickel is, however, characterized by high thermal expansion and must therefore be well bonded; otherwise it may buckle and form blisters when heated. Electroplated chromium over nickel is not desirable, because of the formation of cracks which not only may cause rapid deterioration of the chromium but may also extend through the nickel layer.'

Structure of Nickel-Phosphorus Deposits made by the Kanigen Process

A. W. GOLDENSTEIN, W. ROSTOKER, F. SCHOSSBERGER and G. GUTZEIT: 'Structure of Chemically Deposited Nickel.'

Jnl. Electrochemical Soc., 1957, vol. 104, Feb., pp. 104–10.

The work reported covers part of a programme of fundamental research sponsored by General American Transportation Corporation at the Armour Research Foundation, in the course of development of the Kanigen chemical-immersion process for deposition of nickel.

The paper opens with a discussion of the basic reactions involved in chemical-immersion processes for deposition of nickel, with particular reference to those characteristic of procedure based on catalytic reduction of nickel ions in the presence of hypophosphite ions. Some account is given of modifications which have been introduced to secure stability of the solutions and satisfactory large-scale operation of plant.

A detailed account is then given of X-ray and metallographic examination of chemically-reduced nickel coatings deposited on various types of substrate. Illustrations are shown of the respective coatings, and the effect of heat-treatment on the chemically-produced deposits is demonstrated. It is shown that the deposits (which contain 7–10 per cent. of phosphorus) are characterized by a dense, amorphous structure, which is apparently unaffected by the nature of the substrate, and the method by which it has been prepared, also by the thickness of the coating. The deposits made by this process conform exactly to the surface contour of the substrate. The coatings showed no porosity, but there were striations in etching intensity, interpreted as due to variations in phosphorus content. There was also evidence of growth faults originating from roughness of the surface of the substrate.

The as-deposited state of chemically-reduced nickel is highly metastable, and at temperatures of 300°C. or above reverts rapidly to the equilibrium condition of a phase mixture of crystalline nickel and crystalline Ni_3P. The state of dispersion of Ni_3P can be used as a means for promoting and controlling the hardness of heat-treated chemically-reduced nickel. The finer the dispersion, the harder is the coating: hardness tests on specimens heated at various temperatures are shown in the report.

Growth and Oxidation of Thermally Deposited Nickel Films

L. E. COLLINS and O. S. HEAVENS: 'The Epitaxial Growth and Oxidation of Nickel, Cobalt and Iron on Rocksalt.'

Proc. Physical Soc., 1957, vol. 70, Mar. 1, pp. 265–81.

The structure and orientation of films of iron, nickel and cobalt deposited by thermal evaporation on rocksalt were examined by electron diffraction, as were also the oxides which formed spontaneously on the epitaxially grown metal films.

Radiographic Determination of Porosity in Metal Coatings

F. OGBURN and M. HILKERT: 'New Test Checks Electroplating Porosity.'

Iron Age, 1957, vol. 179, Mar. 7, pp. 123–6.

This article gives a simplified and condensed account of the radiographic test method developed as a result of research at the National Bureau of Standards under A.E.S. Research Project 13. For fuller report see paper abstracted in *Nickel Bulletin* 1957, vol. 30, No. 4, p. 55. (See also note in *Metal Finishing* 1957, vol. 55, Mar., p. 62.)

NON-FERROUS ALLOYS

Forming and Shaping of Non-Ferrous Metals

INST. METALS: 'The Final Forming and Shaping of Wrought Non-Ferrous Metals.'
Inst. Metals Monograph and Report Series No. 20, 1956; 128 pp.

This volume contains final forms of papers presented at the Symposium held in March 1956, together with discussions.

For abstracts of the papers (which appeared in the Journal of the Institute for February and March 1956) see *Nickel Bulletin* 1956, vol. 29, No. 5, pp. 87–8.

Control of Quality in Non-Ferrous Castings: Symposium

A session of the 1957 Annual Meetings of the Institute of Metals, held in April, was devoted to a discussion on metallurgical aspects of control of quality in non-ferrous castings. The papers presented were published in advance in the Journal of the Institute: references are shown below. The large number of figures and tables presented, together with the extensive supporting *bibliographies*, are valuable features of the respective reports.

A. R. MARTIN: 'The Rôle of Statistical Methods in Controlling the Quality of Non-Ferrous Castings.'
Jnl. Inst. Metals, 1956–57, vol. 85, Feb., pp. 209–26.

Although aircraft designers and designers in other fields of engineering are already making considerable use of statistical methods, such procedure is not yet generally adopted in foundries. It is the purpose of this paper to demonstrate the potential usefulness of statistical methods in facilitating correct interpretation of the information provided by inspection records. Further, the author provides evidence of the manner in which such methods may be used to evaluate the production data on which systems of foundry control are based.

A. V. CARLESS: 'Metallurgical Control of Quality in the Production of Aluminium Alloy Castings', *ibid.*, pp. 227–35.

A review of some of the more important aluminium casting alloys in common use, with discussion of methods adopted in large-scale production.

The emphasis is on metallurgical considerations, and the points discussed include control of composition, control of material, melting practice (melting pots, treatment of the metal, including de-gassing, grain refinement, and temperature control), casting practice, handling and identification, heat-treatment, and inspection. In addition to the information generally applicable to aluminium-base alloys, attention is drawn, in various sections of the paper, to precautions required with individual compositions.

E. F. EMLEY and P. A. FISHER: 'The Control of Quality of Magnesium-base Alloy Castings', *ibid.*, pp. 236–54.

The paper covers methods used in production of sand-castings and gravity die-castings. It deals with three aspects of control: (1) methods employed with the aim of attaining high-grade castings, (2) routine inspection procedure, and (3) study of defects for the purpose of devising remedial methods. Some typical defects which may occur in magnesium castings are illustrated. The paper closes with observations on general production procedure which favours attainment of high quality.

R. W. RUDDLE and A. CIBULA: 'The Metallurgical Principles of the Control of Quality of Non-Ferrous Castings', *ibid.*, Mar., p. 265–92.

The authors present a detailed review of factors involved in the occurrence of defects in non-ferrous castings and discuss the scientific basis of methods which can be used to avoid such defects. The paper is based on extensive studies carried out, over a long period, by the British Non-Ferrous Metals Research Association, correlated with the prolific literature of the subject.

The subject is dealt with in three main sections, the contents of which are indicated below:

The Flow of Liquid Metals (the gating system; filling the mould cavity).

Mechanism of Freezing: Heat flow in castings (rate at which castings freeze; mechanism of freezing in metals and alloys, and the bearing of these factors on the incidence of shrinkage porosity and on methods of feeding; other defects arising during solidification, e.g., hot tears and segregation).

Control of Melt Quality (gas content, grain refinement, elimination of non-metallic inclusions, test-bar design).

A. R. FRENCH: 'The Metallurgical Control of Quality in the Production of Copper-base Alloy Castings', *ibid.*, pp. 293–317.

The paper covers the copper-base alloys most commonly used for castings, i.e., those included in B.S. Schedule No. 1400. It is concerned mainly with sand castings. In the opening section consideration is given to the composition and constitution of the alloy groups under review (copper-tin-base, copper-zinc-base and copper-aluminium-base series). The influence of basic composition and microstructure, on the properties of the alloys, is then reviewed, and some of the uses of the individual types are indicated. This is followed by a section on the influence of impurities, with particular emphasis on the effects of reducing gases.

Production methods used for control of quality are then considered, as adapted for the respective groups of material listed above. Tests used to evaluate metal quality are discussed.

D. R. WOOD and J. F. GREGG: 'Control of Quality in the Production of Nickel-Alloy Sand Castings', *ibid.*, pp. 319–29.

The authors limit their paper to discussion of factors

which are important in the production of high-grade nickel-base casting alloys: relatively little attention is given to general principles of good founding practice which are applicable also to other alloys.

The paper gives a review of the effects of small variations in composition, on the mechanical properties of nickel-base alloys containing, in varying combinations, one or more of the following elements; carbon, silicon, copper, chromium, molybdenum, tungsten and tin, and containing also small amounts of iron and manganese. Composition and properties are shown for the principal nickel-base casting materials: nickel, graphitic nickel; Monel, H Monel and S Monel (nickel-copper-base alloys containing varying amounts of silicon); Hastelloy B (nickel-molybdenum-base alloy containing a small percentage of iron) and Hastelloy C (nickel-molybdenum-iron modified by additions of chromium and tungsten); Inconel (nickel-chromium-iron alloy). Freezing ranges and pouring temperatures for these materials are shown, and typical mechanical properties obtainable in castings of the various alloys are recorded.

Consideration is given to the significant influence of minor elements in nickel-base alloys: the effects of carbon, silicon, sulphur, and lead are reviewed, and methods of controlling composition within limits optimum for casting alloys are discussed. Only limited information is available on the welding qualities of nickel-alloy castings, but attention is directed to the benefits derived from addition of niobium to Monel and to the improved results obtained by treatment of the molten alloy with gaseous oxygen.

Castability of the nickel-base alloys is evaluated on the basis of 'fluidity' and 'casting quality'. (For the significance of this classification and for further information on the casting qualities of the alloys, see earlier paper by these authors, abstracted in *Nickel Bulletin*, 1957, vol. 30, No. 4, p. 55.)

Discussion of methods for control of quality includes observations on general principles applicable to the production of nickel alloys, e.g., similarity to those obtaining in the melting of steel, and importance of time and temperature during melting. Suggestions are made with regard to impurity limits for raw materials to be used in production of nickel-alloy castings.

These recommendations are followed by consideration of the choice of melting furnaces and of refractory linings. Details are given of melting procedures for electric-induction and arc furnaces, including the use of 'boiling' and of oxygen-lancing for degassing and refining. It is shown that by oxygen-lancing a high level of properties can be achieved in nickel-copper and nickel-chromium-iron alloys made from scrap-metal charges. (See also note on the influence of this treatment on weldability of Monel, above.) Techniques employed in alloying and deoxidation of nickel-base alloys are also reviewed and desulphurization treatment is described.

In considering moulding and casting, it is pointed out that the high melting point of these nickel alloys and the large liquid and solid contraction which occurs, combined with the relatively low strength of the materials at temperatures immediately below their solidus ranges, necessitates the use of highly refractory moulding sands, substantial feeder systems, and mould designs which permit unhindered contraction of the metal in both the liquid and the solid states.

A brief note is added on inspection methods used for quality control. A keel-type test-bar casting found suitable for evaluation of quality of nickel-base alloys is illustrated.

H. J. SHARP: 'The Control of Quality of Pressure Die-Castings', *ibid.*, pp. 330–8.

Methods adopted for quality control in pressure die-castings are discussed in sections dealing, respectively, with pressure die-casting machines, the main types of defect found in pressure die-casting, alloys used for production of such castings (aluminium, magnesium-, and zinc-base alloys), design of casting and die, heat balance in the die cavity, metal flow into the cavity, injection pressure, process variables and their control, production running of the die, and inspection procedure.

S. L. FRY: 'Non-Destructive Testing in the Control of Quality of Non-Ferrous Castings', *ibid.*, Apr., pp. 361–6.

Brief reference is made to the following methods: visual inspection, liquid-penetrant methods, pressure testing, ultrasonic testing, and fluoroscopy. The paper is concerned mainly with the use of radiographic examination of castings, and the interpretation of the results. Typical defects detectable in radiographs are illustrated and discussed: these include shrinkage, gas porosity, oxide inclusions, cracks, tears and other faults.

Nickel and Nickel Alloys: Literature Review

See abstract on p. 84.

Inconel Alloys: Data Sheets

See abstract on p. 96.

Nickel-Tungsten-Carbon Alloys: Constitution

K. WHITEHEAD and L. D. BROWNLEE: 'Ternary Phases in the Nickel-Tungsten-Carbon System.' *Planseeberichte f. Pulvermetallurgie*, 1956, vol. 4, Dec., pp. 62–71.

The ternary system was studied by X-ray methods from 0 to 100 at. per cent. nickel and 50 to 100 at. per cent. tungsten. An isothermal diagram at 1200°C. is given.

Formation of Copper-Nickel Alloys from Precipitated Carbonates

W. K. HALL and L. ALEXANDER: 'X-Ray Studies on the Formation of Copper-Nickel Alloys from the Precipitated Basic Carbonates.'

Jnl. Physical Chemistry, 1957, vol. 61, Feb., pp. 242–4.

Report on study of the formation of copper-nickel alloys by low-temperature reduction of the mixed oxides with hydrogen. It is demonstrated that even when two oxidic phases are present, on reduction a single metallic phase only is formed and, in this phase, compositional variations, if present at all, cannot exceed 3 per cent. It is concluded that the oxidic phases formed in the system studied are pure CuO and an NiO phase in which up to 35 per cent. of the nickel atoms have been substituted by copper.

Constitution of Manganese-Nickel Alloys

See abstract on p. 93.

Age-Hardening in Nickel-Tin Alloys

T. MISHIMA, R. HASHIGUCHI and Y. KIMURA: 'Age-Hardening of Nickel-Tin Alloys.'

Nippon Kinzoku Gakkai-Shi, 1956, vol. 20, June, pp. 347–50.

Examination of age-hardening effects in binary alloys of nickel containing 14–16 per cent. of tin, quenched in water and aged for various periods at temperatures in the range 550°–625°C. Magnetic properties, Vickers hardness, and structure were correlated with age-hardening treatment. The form of the magnetization/temperature curves and the change of lattice parameter indicated the occurrence of discontinuous precipitation.

Ageing Phenomena in Nickel-Titanium Alloys

C. BÜCKLE and J. MANENC: 'Observation, during Ageing of a Nickel-Titanium Alloy, of a Preliminary Condition of Pre-Precipitation, followed by a Transitory Condition.'

Comptes Rendus, 1957, vol. 244, Mar. 18, pp. 1643–6.

The alloy examined, containing 9·26 per cent. of titanium, is one of a series of binary compositions investigated in an attempt to explain phenomena in X-ray diffraction observed during research on 80–20 nickel-chromium-base age-hardening alloys.

The specimens, after homogenizing treatment, were treated (by cold-work and re-crystallization heat-treatment) to produce material of fine and of coarse grain, and after the final heating at 1080°C. were water-quenched and subsequently tempered at 500°, 600°, 700°, 800° and 850°C. After treatment at temperatures of 600°C. upwards precipitation was observed, and when ageing was at temperatures and for periods sufficiently long, three distinct stages of transformation were found: (1) an 'impoverished' matrix; (2) the unstable phase designated γ'; and (3) the stable Ni_3Ti phase η. Photomicrographic examination confirmed the conclusions drawn from the X-ray data. The effects observed are broadly similar to those occurring, at lower temperatures, in aluminium-base alloys.

Properties of Nickel-Molybdenum Alloys

See abstract on p. 99.

Magnetic Susceptibility of Copper-Nickel Alloys

E. W. PUGH, B. R. COLES, A. ARROTT and J. E. GOLDMAN: 'Magnetic Susceptibility of Dilute Alloys of Nickel in Copper between 2·5°K. and 295°K.'

Physical Rev., 1957, vol. 105, Feb. 1, pp. 814–18.

Report of measurements on binary copper alloys containing 0·59, 1·16 and 2·48 at. per cent. of nickel. At room temperature all the alloys were found to be diamagnetic: the numerical value of the susceptibility decreased with increasing nickel content, a conclusion which is in agreement with the results obtained by KAUFMANN and STARR (*ibid.*, 1943, vol. 63, p. 445). At the lower temperatures within the range used the temperature-dependence of magnetic susceptibility was found to be not so pronounced as had been suggested by the earlier investigators.

Monel Gauze in Aircraft De-Icing Equipment

'Propeller De-Icing. Electrothermal Mats for Viscounts.'

Flight, 1957, vol. 71, Mar. 1, pp. 283–4.

Illustrated description of cyclic de-icing equipment applied to the propeller blades of Viscount aircraft. This de-icer, which embodies an electric heating element incorporating a resistance wire, is of a specialized design developed by Rotol Limited, and the heaters are now used as the basis for the electrical overshoe which forms an integral part of the de-icing system fitted on the Vickers Viscounts. To protect the heaters against stones or grit which may be sucked up from the runways, Monel gauze is placed over the heater, and insulated from it.

Monel in Sewage Plant

See abstract on p. 102.

Protection of Offshore Structures by Monel Sheathing

See abstract on p. 102.

Permanent-Magnet Materials and their Uses: Review

See abstract on p. 96.

Welding of Nickel-Aluminium-Bronze Propellers

J. L. CAHILL: 'Welding of Nickel-Aluminium Bronze.'

Reprint from *Welding Jnl.*, Dec. 1956; 8 pp.

See abstract in *Nickel Bulletin*, 1957, vol. 30, No. 3, p. 39.

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NICKEL-IRON ALLOYS

Constitution of Iron-Nickel and Manganese-Nickel Alloys

A. HELLAWELL and W. HUME-ROTHERY: 'The Constitution of Alloys of Iron and Manganese with Transition Elements of the First Long Period.'

Philosophical Trans., Royal Soc. Lond., Ser. A., 1957, vol. 249, Mar., pp. 417–59.

Report of study of the constitution of iron-rich and manganese-rich binary alloys with titanium, vanadium, chromium, cobalt, nickel and copper, investigated by specially accurate thermal analysis, supplemented by microscopical and X-ray examination. Metals of high purity were used.

Magnetic Materials: Composition, Properties and Uses

AMER. INST. ELECTRICAL ENGINEERS: 'Conference on Magnetism and Magnetic Materials.'

Published by the Institute, 1956; 370 pp.

Papers (or abstracts of papers) presented at a Conference sponsored by the Magnetics Sub-Committee of the A.I.E.E. Committee on Basic Sciences, in co-operation with the American Physical Society and the American Institute of Mining and Metallurgical Engineers. The meeting was convened in an attempt to bring together physicists, engineers and metallurgists interested in the study of magnetism and magnetic materials.

The papers, contributed by research workers and industrialists, are presented in sections classified as shown below:

Basic Magnetism
Magnetic Susceptibility and Resonance Phenomena
Metallurgy and Structure
Permanent Magnets and Fine Particles
Magnetic Amplifiers and Switching
Ferrites
Apparatus and Magnetic Design.

In addition to the general interest of a number of the subjects in relation to nickel and nickel alloys, several papers deal specifically with nickel-containing materials: notes on points of outstanding interest in this connexion are given below.

Magnetic Susceptibility and Resonance Phenomena

E. BOTH: 'Static and Dynamic Magnetization Characteristics of Magnetic Amplifier Core Materials', pp. 65–79.

Report of tests made on cores of silicon-iron, nickel-iron (50–50 and 65–35 per cent.), molybdenum-Permalloys and magnesium-manganese ferrites.

Metallurgical Structure

J. F. LIBSCH and G. P. CONARD: 'Metallurgy and Magnetic Materials', pp. 80–8.

Discussion of the following factors, as affecting properties and uses of magnetic materials: deformation and annealing, modifications which can be effected by alloying, fabrication processes. The paper is accompanied by a useful selected *bibliography*.

U. ROESLER: 'A Study of Ferrous Ternary Diagrams in Relation to Magnetic Interactions: the Fe–Ni–Al System', pp. 89–91.

The experimental work reported is considered in relation to conflicting conclusions which have been drawn with regard to the effect of aluminium on the magnetic transformation of iron. The results are correlated with a report by ZENER (*Jnl. of Metals*, 1955, vol. 7, pp. 619–30).

C. E. RICHARDS, E. V. WALKER and A. C. LYNCH: 'Powder Metallurgy for Research into Ferromagnetic Materials', pp. 131–3.

The authors demonstrate the usefulness of powder-metallurgy technique for the production of magnetic alloys. The metal powders should be of high purity and small particle size (powders made by the carbonyl process are suitable) and may, if required, be de-oxidized and decarburized by low-temperature heat-treatment in wet hydrogen. The powders are mixed, and sintered at about 1200°C. The sintered block is then cold-rolled to strip, which has a density equal to that of strip prepared from melted and cast alloys. Production by this technique has the following advantages:

Close control of composition is ensured. The precise consistency which can be secured is demonstrated by reference to 4–79 types of Permalloy alloy.

Absence of impurities. The authors review the impurities (oxides, sulphides or metals) which may be found in alloys made by melting and casting, and briefly discuss some of the deleterious effects which they may exert. With regard to alloys made by conventional methods, particular attention is drawn to the effect of impurities on deterioration during annealing, on change in permeability as a function of thinness of strip, and on irregularity in coercive force.

The usefulness of the powder-metallurgy technique for preparation of samples for electrical tests is emphasized and methods by which tests can be made on small representative specimens are described.

See also next abstract.

H. EVANS, C. GORDON SMITH and D. K. WORN: 'The Use of Powder Metallurgy in the Production of Soft Magnetic Materials', pp. 134–7.

The developments described were the outcome of co-operative experiments by the General Post Office Engineering Department (see previous abstract) and The Mond Nickel Company Limited, followed up, on a production basis, by Messrs. Henry Wiggin & Company Limited. The process used comprises weighing and mixing of the component powders, pressing, and sintering, followed by normal working procedure, which may include hot working and cold rolling, with appropriate intermediate annealing.

The mixed and pressed (carbonyl) powders are pre-treated for four hours at 600°C. (to remove carbon, oxygen and nitrogen) and the final sintering

is carried out at 1200°C. for four hours. This treatment results in linear shrinkage of about 6–7 per cent., and in alloys correctly mixed and sintered in this manner no evidence of inhomogeneity has been observed. The sintered bars are heated in hydrogen at 1050°–1100°C. and are forged in a single stage to billets about $\frac{1}{4}$ in. thick. They are then vapour-blasted, to remove any slight surface contamination, annealed in hydrogen at 1000°C. and cold-rolled to the final thickness, with intermediate annealings. X-ray diffraction measurements show that such processing gives a finished product of completely random-oriented structure.

Molybdenum–Permalloy Alloys

Tests on a nickel-iron-molybdenum-copper alloy (77–14–4–5 per cent.), made by the method described above, led to the following conclusions:

(1) *Effect of Composition.* Variations in the proportions of the constituent elements have a critical influence on permeability, and emphasize the significance of the close control obtainable by powder-metallurgy technique.

(2) *Effect of Heat-Treatment.* A further advantage of the powder-metallurgy alloys is that the presence of water vapour in the hydrogen atmosphere during final heat-treatment has no ill effects, although it has invariably proved harmful in the case of alloys made by melting. This difference is believed to be due to the influence, in the melted alloys, of impurities such as silicon, aluminium and magnesium. Sub-surface oxidation of these elements during heat-treatment in the presence of water vapour gives rise to highly dispersed inclusions of silica, etc., producing a surface layer which is characterized by small grain size and low magnetic permeability. Further investigations show that raising the temperature and/or time of the final heat-treatment and/or of the sintering operation may effect considerable additional improvement in magnetic properties: The use of the better initial alloy obtained by the powder-metallurgy technique makes it possible to attain such results by less drastic alterations of treatment than would be necessary for melted alloys.

(3) *Effect of Thickness of Strip.* The falling-off in permeability with decrease in thickness of strip which is usually found in melted-alloy strip does not occur with strip made by the powder method, due to the absence of the low-permeability layer referred to in the preceding section. A permeability of 30,000 can be maintained, in works conditions, in strip 0·001 in. thick.

Alloys having Square Hysteresis Loops (Nickel 65%)

Alloys of this type have been produced by methods similar to those described above, except that preferred orientation is induced by heat-treatment in a magnetic field. By comparison with strip made from melted alloys, the powder-made alloys show marked reduction in coercive force, and, by addition of molybdenum, an increase in electrical resistivity has been achieved, with consequent reduction of eddy-current losses.

The consistent level of properties attainable in high-permeability alloys prepared by powder metallurgy permits designing to stringent specifications, and the resulting advantages should be appreciable, for example, in designing communications transformers. In pulse transformers the advantages of the powder-made strip are particularly significant in view of the necessity for using very thin strip to reduce eddy-current losses under pulse conditions. In both the high-permeability and the square-loop alloys the associated characteristics of low coercive force and steepness of the B/H curve should make possible important advances in the design of magnetic amplifiers and reactors for contact rectifiers.

W. R. HIBBARD: 'Preferred Orientations and Magnetic Properties of Rolled and Annealed Permanent-Magnet Alloys', pp. 184–91.

Pole figures, torque curves and coercive force were determined for the following permanent-magnet alloys, in the rolled and annealed condition:

Cunife (copper-nickel-iron)
Cunico (copper-nickel-cobalt)
Silmanal (silver-manganese-aluminium)
Vicalloy I and II (cobalt-iron-vanadium)
Heusler's alloy (copper-manganese-aluminium)

J. R. HANSEN: 'The Anomalous Behaviour of Alnico V in the Sub-Curie Temperature Region of 1000°F. through 1450°F.', pp. 198–204.

The high coercivity of Alnico V alloy is, according to current theory, due to the critical separation of compound precipitates, which permits magnetization of the domains by rotation instead of by boundary displacement. The author of this paper presents data regarding the behaviour of the alloys in the sub-Curie region 1000°–1450°F. (538°–788°C.) which is not readily explicable on the basis of compound precipitation. It is postulated that there is strong indication of an order-disorder reaction. The loss in coercivity which occurs on heating the alloy to successively higher temperatures from 1150° to 1450°F. (620° to 788°C.) would represent a condition of increasing disorder, i.e., short-range order, and the increase in coercivity on ageing or on re-ageing at 1075°F. (580°C.) would correspond to a condition of approaching long-range order. It is further suggested that the possibility of imparting directionality to Alnico V by a heat-treatment under the influence of a magnetic field is in some way associated with the ordering reaction occurring during transformation. It is pointed out that if this hypothesis is correct it may be possible, by thermo-magnetic treatment, to develop in platinum-cobalt magnet alloys properties much superior to any which have yet been achieved.

See also following abstract

E. A. NESBITT and H. J. WILLIAMS: 'New Facts concerning the Permanent-Magnet Alloy Alnico V', pp. 205–9.

Earlier work by the authors and their colleagues had shown that the coercive force of alloys of the Fe_2NiAl composition is due primarily to the shape anisotropy of the plates of precipitate phase. The present paper reports experiments on Alnico V, which confirm the conclusions drawn from the earlier work.

Magnetic Amplifiers and Switching

C. E. WARD and M. F. LITTMANN: 'Relation of D.C. Magnetic Properties of Oriented 48% Nickel-Iron to Magnetic Amplifier Performance', pp. 228–35.

In order to improve the characteristics of cores for magnetic amplifiers close knowledge of the influence of metallurgical variables, on magnetic performance, is essential. This paper is designed to provide some reference information which will be of common interest to the producer of the cores and the designer using them. The material used in the tests described was a 48 per cent. nickel-iron alloy, in which magnetic properties relevant to amplifier performance were studied as affected by crystal or grain orientation, thickness of tape, and coercive force. Orientation and coercive force were found to be of major importance, and the nature of their respective effects is demonstrated and discussed.

N. I. ANANTHANARAYANAN: 'Soft Magnetic Materials with Rectangular Hysteresis Loops', pp. 236–46.

This paper comprises a review of information available from the literature; it is supported by a *bibliography* of 86 references.

Consideration is first given to the structural conditions necessary to ensure rectangular hysteresis loops, and the factors which favour their attainment. A review is then made of metallurgical and other variables which are of significance in this connexion, e.g., impurities, structural orientation, recrystallization, domain orientation, grain size, lattice changes during heat-treatment, stress.

The final section of the review contains a discussion of materials in which square hysteresis loops can be induced; these include nickel-iron-base alloys of various compositions, binary alloys of iron with silicon, cobalt and aluminium, and ferrites of various types.

G. H. HOWE: 'Dynamax, a New Crystal and Domain-Oriented Magnetic Core Material', pp. 264–72.

The paper deals with composition, treatment and properties of an alloy containing nickel 65, iron 33, molybdenum 2, per cent., which has been developed, under the name of Dynamax, in the form of thin tape for toroidal cores.

Studies on a 65 per cent. nickel-iron alloy had shown that heat-treatment in a magnetic field is more effective on strip which has been grain-oriented than on strip of low polycrystalline alignment. Thermal treatment, in a magnetic field, of 0·003-in. Permalloy tape having a cube texture was found to raise the values of d.c. maximum permeability to about 1,000,000, but this extreme degree of magnetic softness could not be effectively utilized for a.c. applications, due to the low electrical resistivity of the alloy.

Resistivity was approximately doubled by alloying with molybdenum. Tape 0·002-in. thick and ½-in. wide, completely annealed, and wound on a toroidal core, was found to have a d.c. maximum permeability of 338,000, a residual flux density of 11,740 gauss, and a coercive force of 0·029 Oersted. The dynamic hysteresis loop of this material proved to be narrower than that of the 50–50 nickel-iron alloy Deltamax and of straight 65 Permalloy, hence its designation Dynamax. Much detailed information is given on the influence of heat-treatment on the modified alloy, and the properties which can be developed in such materials are discussed in relation to structure. It has been found possible, by suitable processing, to produce in the 0·002-in. tape a maximum permeability of 1,600,000, residual flux density of 12,000 and 0·0065 coercive force.

Ferrites

J. M. BLANK and N. SCHWARTZ: 'Initial Permeability as a Function of Temperature for Certain Ni-Zn Ferrites', pp. 290–1.

It has been observed that nickel-zinc ferrites over a fairly broad range of composition, when sintered at appropriate temperatures, show a characteristic form of initial-permeability/ambient-temperature curve. Typical examples are shown in this paper. The authors propose an explanation for these characteristics.

H. SHENKER: 'The Magnetic Anisotropy of Cobalt Ferrite and Nickel Ferrite', p. 370.

Magnetic isotropy, in the two types of ferrite, was measured from 20°K. (−253°C.) to their respective Curie temperatures (approximately 800° and 860°K.; 527° and 587°C.), using torque methods.

L. G. VAN UITERT: 'High-Resistivity Nickel Ferrites: The Effect of Minor Additions of Manganese or Cobalt', pp. 299–304.

Nickel ferrite, as usually prepared, has a d.c. resistivity of 10^4 ohm/cm. but it has been found that by incorporating small amounts of manganese or cobalt the values can be raised to the order of 10^{10} or 10^{11} ohm/cm. Materials containing the metals in various ratios were examined. A tentative explanation is advanced for the modifications effected by the addition elements.

Apparatus and Magnetic Design

R. E. FISCHELL: 'Magnetic Effects of Compressional Stress at Low Field Intensities', pp. 315–20.

Magnetic materials are frequently used in the form of a clamped stack of laminations, and the direction of the clamping stress is perpendicular to the plane of the laminations and perpendicular to that of the

applied magnetic field. This paper reports tests on toroidal laminated cores of nickel-iron-base and other important magnetic materials, describing the effect of transverse compressional stress on the a.c. and d.c. magnetic properties at very low field intensities. Under the action of increasing compressional stress each of the materials tested exhibited a decrease in low-field permeability, and an a.c. magnetization curve which was shifted downwards, but the extent of these changes varied from one material to another.

C. D. OWENS: 'Stability Characteristics of Molybdenum-Permalloy Cores', pp. 334–9.

The information given in this paper is closely similar to that appearing in *Electrical Engineering*, 1956, vol. 75, pp. 252–6; see abstract in *Nickel Bulletin*, 1956, vol. 29, Nos. 8–9, p. 165.

Powder-Metallurgy Symposium

See abstract on p. 84.

Permanent-Magnet Materials and their Uses: Review

A. EDWARDS: 'Permanent Magnets.'
Electrical Energy, 1957, vol. 1, Jan., pp. 146–51; Feb., pp. 178–85.

In Part I the author discusses the current trend towards employment of permanent magnets in place of electromagnets, with particular reference to the saving in space which can be effected by use of the powerful magnet materials developed during recent years. Typical examples of some of the newer uses are described and illustrated, and size economies are demonstrated by photographs of magnets of the older materials, e.g., cobalt steel, and of the newly developed types of Alnico and Alcomax alloys.

Part II contains an outline of the development of permanent-magnet materials, with comparisons of the properties now attainable in regular production with those characteristic of magnet materials available in earlier years. The article includes a valuable tabular summary of the compositions and properties of known types of permanent-magnet material, with information on the country of origin of the respective types. Some details are also given of heat-treatment, which is so important a factor in securing optimum properties in many of the materials discussed.

CAST IRON

Nickel-Iron Electrodes for Repair Welding of Marine-Engineering Components

H. C. WAUGH: 'Welding Repair Costing $600 Reclaims $8,000 Engine Blocks.'
Reprint from *Welding Jnl.*, Aug. 1956; 4 pp.
See abstract in *Nickel Bulletin*, 1956, vol. 29, Nos. 10–11, p. 187.
Issued by INTERNATIONAL NICKEL CO., INC.

HEAT- AND CORROSION-RESISTING MATERIALS

Nickel-containing Materials in the Rover Gas Turbine

'Rover 2S/100 Gas Turbine.'
Autocar, 1957, vol. 106, Mar. 15, pp. 354–7.

Description, with cut-away diagram, of the Rover 2S/100 gas-turbine-driven automobile. The information given includes particulars of the materials used for the major engine parts, e.g., reference is made to alloys of the Nimonic series used for the turbine blading and for bolts and other components, and to nickel-chromium stainless-steel sheet in the heat-exchanger.

Inconel Alloys: Data Sheets

INTERNATIONAL NICKEL CO., INC.: 'Engineering Properties of Cast Inconel Alloys.'
Published Dec. 1956; 8 pp.

The information given relates to three types of Inconel, of which the compositions are shown below.

The brochure contains reference data on the following aspects: physical constants (all grades); hot hardness (up to 1600°F.: 870°C. for 'S' Inconel); low-temperature impact-resistance (Inconel); elevated-temperature tensile properties (investment-cast Inconel); resistance to wear and galling ('S' Inconel); mechanical properties and hardness at normal temperatures (all grades); corrosion-resistance (general information); machining technique (all grades); welding and brazing (Inconel and the welding-grade alloy). The high-silicon S-grade alloy is not considered weldable.

Nominal Compositions*

Alloy	Ni (+Co) %	Cu %	Fe %	Mn %	Si %	Cr %	S (†) %	C %	Nb(+Ta) %
Inconel	71·5	0·5	8·0	1·0	2·0	16·0	·008	0·20	—
'S' Inconel ..	68·0	0·5	8·5	1·0	5·5	15·5	·008	0·20	—
Weldable Grade Inconel	68·5	0·5	9·0	1·0	1·6	15·5	·008	0·20	1·00-3·00

* Values shown are for normal production: they are subject to minor variations for individual patterns and for various uses.
† Should be as low as possible.

Limiting compositions for specification purposes are also suggested.

INTERNATIONAL NICKEL CO., INC.: 'Inconel '713C', Nickel-Chromium Cast Alloy; Basic Data.'

Published Mar. 1957; 4 pp.

The alloy described is characterized by high rupture strength at 1700°F. (925°C.), combined with excellent resistance to thermal fatigue and good castability. It has been developed specifically for use in gas-turbine blading. The following nominal composition is given: carbon 0·20 max., manganese 1·0 max., sulphur 0·015 max., silicon 1·0 max., chromium 11·0–14·0, molybdenum 3·5–5·5, titanium 0·25–1·25, aluminium 5·5–6·5, iron 5·0 max., niobium+tantalum 1·0–3·0 per cent., nickel remainder.

The information given covers density, thermal-fatigue resistance, high-temperature tensile properties, rupture properties and creep behaviour.

INTERNATIONAL NICKEL CO., INC.: 'Inconel '700' Age-Hardenable Nickel-Cobalt-Chromium Alloy: Basic Data.'

Published Nov., 1956; 4 pp.

This alloy, recently developed as a heat-resisting material, has good strength at high temperatures, combined with resistance to corrosion and oxidation. It can be forged and machined, and is weldable. Although primarily intended for blading in aircraft gas turbines, its properties make it suitable for use in many other high-temperature engineering applications.

The following is given as a typical composition: carbon 0·16, manganese 0·10, silicon 0·25, sulphur 0·008, chromium 15·00, titanium 2·20, aluminium 3·0, cobalt 28·0, molybdenum 3·0, iron 7·0, nickel 45·0, per cent.

Information is tabulated on the following physical properties: density, modulus of elasticity, specific heat, coefficient of thermal expansion, thermal conductivity. Graphs show rupture life and tensile properties at various temperatures up to 1800°F. (980°C.).

Nickel and Nickel Alloys: Literature Review

See abstract on p. 84.

Protection of Molybdenum by Electrodeposited Coatings

See abstract on p. 88.

Production and Fabrication of Chromium-Manganese-Nickel Stainless Steels

G. W. HINKLE: 'Production and Fabrication of New AISI Types 201 and 202.'

A.S.T.M. Bull., 1957, No. 220, Feb., pp. 47–50; T.P. 37.

Production of high-manganese steels of the A.I.S.I. 201 and 202 Types has until recently been on an experimental basis and much work has been carried out to develop the compositional limits optimum for fabrication as well as for properties. This paper, based on extensive tests made by Republic Steel Corporation, is designed to give practical information on methods which may be used in large-scale production of steels within the composition ranges shown in the table below.

The recommendations made and the opinions expressed cover the following aspects of the subject: melting, blooming-mill operations, conversion of slab to strip product, forging, annealing, pickling, brake- and roll-forming, deep-drawing, polishing, and welding. Some of the major points made are noted below:

Melting of these steels presents no problems other than modifications in practice called for by the high manganese and nitrogen contents of the steels. Conversion of ingot to sheet and strip product requires longer time than is necessary for steels of the 300 series, and more power is required for hot- and cold-rolling of the high-manganese types. Annealing temperatures must be somewhat lower than those used for the 300 series. Pickling solutions should be somewhat more dilute and should be used at temperatures rather lower than those employed in pickling chromium-nickel stainless steels. Grinding and polishing technique used for Type 302 can be employed, and the higher-manganese steels, like the straight chromium-nickel types, may be electrolytically polished, although with some types of bath a minor change in temperature of operation is required. Welding procedure standard for 302 and 301 steels has proved suitable for the high-manganese types: service results have been obtained on spot, seam and projection welding, and on metallic-arc and heliarc fusion welding.

Preliminary experiments have been made to determine the susceptibility of the high-manganese steels to stress-corrosion cracking. The behaviour of the modified steels has been compared with that of steels of the 300 series, in boiling 10-molar solutions of lithium chloride. The results indicate that in this respect the two types of steel are approximately similar.

Chromium-Manganese-Nickel Steels

Type	C %	Si %	Mn %	S %	P %	Cr %	Ni %	N %
201	0·15 max.	1·00 max.	5·5-7·5	0·030 max.	0·06 max.	16·0-18·0	3·5-5·5	0·25 max.
202	0·15 max.	1·00 max.	7·5-10·0	0·030 max.	0·06 max.	17·0-19·0	4·0-6·0	0·25 max.

Deoxidation of Austenitic Chromium-Nickel Steels

R. A. PERKINS and W. O. BINDER: 'Improving Hot Ductility of 310 Stainless.'

Jnl. of Metals, 1957, vol. 9, Feb., pp. 239–45.

This paper is concerned with hot-shortness occurring in single-phase austenitic chromium-nickel steels: it comprises a systematic investigation of the influence of deoxidizers, on susceptibility to low ductility as exemplified by short-time tensile tests, at 2400°F. (1315°C.). The steel used was of the following nominal basis composition: chromium 25, nickel 20, carbon 0·03, nitrogen 0·04, sulphur 0·01, phosphorus 0·01, per cent., iron balance. Silicon and manganese were controlled at 0·20–0·70 and 1·0–1·5 per cent., respectively, except in heats in which the effects of those elements were intentionally varied.

The eight deoxidizing elements studied were silicon, manganese, vanadium, aluminium, titanium, zirconium, cerium (rare earths) and calcium. Initially the tests were made on hot-worked specimens, in order to minimize effects of chemical segregation and variations in grain size, but the study was later extended to include ingot metal.

The results are shown in a detailed series of graphs and photomicrographs indicating the nature, size and distribution of the inclusions found in the specimens treated with the respective deoxidizers, and the hot-ductility curve is correlated with the amounts of deoxidizer used.

It is demonstrated that all the deoxidizers studied could significantly improve hot ductility and that the degree of improvement effected was dependent on the residual amount of the deoxidizer (except in the case of calcium, which was not studied on the residual-quantity basis). Ductility of steels treated with vanadium, titanium and zirconium passed through a maximum as the additions were increased and it is considered that fall in ductility after this maximum is reached may be associated with formation of duplex austenite-ferrite structures. The effect demonstrates the fact that too high a residual content of a deoxidizer may be as harmful as too small an amount.

With one exception, the initial increase in hot ductility of the steel in the hot-worked condition was associated with a significant change in the types of oxide inclusion present. The observations made suggest that the change reflects a fundamental alteration in the composition or the structure of the steel, which alters its hot ductility.

Ferrite, formed in steels treated with vanadium, aluminium and zirconium, had an anomalous effect on hot ductility of the wrought austenitic steel. The ductility of the vanadium-treated steels first increased, whereas that of the aluminium-treated samples remained essentially constant and that of samples treated with titanium or zirconium decreased immediately ferrite appeared in the microstructure. In all cases, ductility fell as significant amounts of ferrite were formed.

With few exceptions, the deoxidation practices used in this investigation resulted in significant reduction in the total oxygen content and changed the non-metallic inclusions to different types. These were characteristic of the specific element added and the amount of deoxidizer required to promote this change was relatively low. It was not found possible to correlate hot ductility with total oxgyen content.

The optimum combination of high ductility at 2400°F. (1315°C.), a fully austenitic structure, and a favourable type of distribution of non-metallic inclusions in the hot-worked steels was obtained by the addition of 0·1–0·2 per cent. of calcium, as a calcium-silicon alloy.

Aluminium, titanium, zirconium and cerium appreciably improved hot ductility, but caused serious segregation of non-metallic inclusions. With titanium and zirconium segregation was associated primarily with nitride inclusions. Silicon, manganese and vanadium produced a more random distribution of inclusions, but the amount of these elements required to ensure hot ductility was somewhat high.

Some supplementary experiments were made on cast steels, to determine the effect of silicon, aluminium, titanium and rare-earth additions. Such additions had no beneficial influence on the hot ductility. All the samples prepared from the ingots showed relatively low ductility which, it is considered, may be associated with coarse columnar grain-size.

While it is recognized that the results of this study cannot be applied directly to commercial practice, it is believed that they should have general significance with regard to the behaviour of hot-worked metal and should lead to improved technique in the manufacture of stainless steel, resulting in greater resistance to hot cracking.

Vacuum Melting of Metals and Alloys

See abstract on p. 84.

Control of Quality in Non-Ferrous Castings: Symposium

See abstract on p. 90.

Corrosion- and Heat-Resisting Nickel-Molybdenum-base Alloy

SOC. AUTOMOTIVE ENGINEERS: 'Alloy, Corrosion- and Heat-Resistant.'

A.M.S. Specification 575. Jan. 15, 1957.

The alloy covered is intended primarily for parts and assemblies such as turbine shrouds and seals, in which the requirement is for oxidation-resistance up to 1600°F. (870°C.), good strength up to 1200°F. (650°C.) and low coefficient of thermal expansion.

Composition limits are given as carbon 0·12 max., silicon 1·00 max., manganese 1·00 max., phosphorus and sulphur each 0·050 max., chromium 4·00–6·00, molybdenum 23·00–26·00, iron 4·00–7·00, vanadium 0·60 max., per cent., nickel + cobalt remainder. (Cobalt, if determined, is to be not more than 2·50 per cent.) Heat-treatment, hardness and tensile properties at 1500°F. (815°C.) are also specified.

Properties of Nickel-Molybdenum Alloys

F. C. MONKMAN, N. J. GRANT and C. F. FLOE: 'Final Report on Development and Testing of Nickel-Molybdenum Alloys.'

U.S. Atomic Energy Commission Report O.R.N.L. 1990, Nov. 28, 1955; 43 pp.

The report covers the investigation of the effect of vacuum melting and of variations in composition, on nickel-molybdenum-base alloys. Such alloys, although primarily used on account of their high resistance to corrosion, also have good mechanical properties at elevated temperatures and are of potential value in applications in which oxidation-resistance is not essential.

The vacuum-melted alloys were forged to $\frac{3}{8}$-in. round rod and in that condition were solution-treated at 2000°F. (1093°C.) for $\frac{1}{2}$ hour and air-cooled. In addition, the effects of two other heat-treatments were examined: (1) $\frac{1}{2}$ hour at 1850°F. (1010°C.) with air-cooling; and (2) $\frac{1}{2}$ hour at 1850°F. (1010°C.) followed by oil-quenching and subsequent re-heating for 16 hours at 1500°F. (815°C.). In addition to the vacuum-melted alloys, a section of commercially made Hastelloy B was examined.

The compositions of the alloys studied are given in the table below.

Stress-rupture tests were made, at 1350°, 1500° and 1650°F. (732°, 815° and 900°C.), on the six alloys, in the three different conditions. Stresses were chosen to give rupture lives of 100–500 hours: the values of stress, rupture life, elongation and reduction in area were measured for each test. Tensile tests at room temperature were made on the alloys in the conditions resulting from the various heat-treatments and further determinations of room-temperature, tensile properties and of hardness were made after exposure of the alloys for 100 hours at 1500°F. (815°C.). Extensive metallographic examination was also carried out.

Among the conclusions drawn from the results are the following. At 1650°F. (900°C.) there is only a slight increase in strength over the whole composition range, an effect which can be correlated with the microstructures of the respective alloys at that temperature. The phase diagram and the photomicrographs indicate that the alloys consist of an alpha solid solution and that in the 36 per cent. molybdenum alloy a small amount of delta was present.

At 1500°F. (815°C.) mechanical strength increased fairly linearly up to 29·8 per cent. molybdenum and then more sharply at the 36·0 per cent. level. It was, however, possible to increase the strength of the 29·8 per cent. alloy by heat-treatment, with the result that both this material and the 36·0 per cent. molybdenum alloy were stronger than the others of the series. The same statement is valid at 1350°F. (732°C.) and the properties can again be related to the phase diagram and the microstructures.

At 100 and 1,000 hours test time commercial Hastelloy B was found to be much stronger than any of the vacuum-melted alloys. The difference is considered to be due to the significant amounts of iron, chromium, cobalt, manganese, silicon and vanadium present in the Hastelloy. The stabilizing effect of the addition elements was apparent in the microstructure.

High-temperature ductility, as assessed by elongation and reduction of area, decreased at 1350° and 1500°F. (732° and 815°C.) at about the 26·0 per cent. molybdenum level, a change which is consistent with the observation that in the 25·6 per cent. molybdenum alloy beta was precipitated at those temperatures as a practically continuous phase. The ductility of the Hastelloy B was equal to, or better than, that of the vacuum-melted materials.

Composition of the Alloys Studied

Vacuum–Melted Alloys	Mo %	Ni %	C %	S %	O %	N %	Other Elements %
1	17·3	bal.	0·02	0·002	0·003	<0·0005	
2	21·0	bal.	0·02	0·002	0·004	<0·0005	
3	25·6	bal.	0·02	0·002	0·002	<0·0005	
4	29·8	bal.	0·02	0·002	0·002	<0·0005	
5	36·0	bal.	0·01	0·002	0·003	<0·0005	
Hastelloy B	27·2	bal.	0·03	0·005	—	—	Cr 0·68
							Fe 4·50
							Si 0·41
							Co 0·36
							Mn 0·63
							V 0·34
							P 0·0005

Room-temperature tensile strength, yield strength and hardness of the vacuum-melted alloys increased with rise in molybdenum content.

Ductility at room temperature increased up to the 29·8 per cent. molybdenum level, with a subsequent slight fall at 36·0 per cent. molybdenum, i.e., in the alloy which contained a precipitate of delta. The strength and hardness values of the Hastelloy B were comparable to those of the vacuum-melted materials but the severe embrittlement observed in the latter did not occur in the Hastelloy alloy after similar heat-treatments. It would thus appear desirable to investigate the effect of small additions of the alloying elements which were present in that material.

Nickel-Tungsten-Carbon Alloys: Constitution

See abstract on p. 91.

Ageing Phenomena in Nickel-Titanium Alloys

See abstract on p. 92.

Stress-Corrosion Cracking: Symposium

ELECTROCHEMICAL SOC., CORROSION DIV.: 'Stress-Corrosion Cracking and Embrittlement.'

Published by *John Wiley & Sons, Inc., New York; Chapman & Hall Ltd., London*, 1956; 202 pp. Price 60/-.

Report on papers and discussion presented at symposium held in Boston in October 1954.

Attention is directed to the symposium organized in 1944 by the American Society for Testing Materials and the American Institute of Mining and Metallurgical Engineers, and to the added practical importance which the subject of stress-corrosion cracking has assumed in the intervening ten years. The scope of the papers, which stemmed from various countries, is believed to give a representative survey of current thought on the subject. The contributions include papers dealing with the phenomena and mechanism of stress-corrosion cracking, the influence of structural factors and the rôle of boundary adsorption, and the occurrence and nature of stress-corrosion cracking in aluminium- and magnesium-base alloys, austenitic steels and mild steels. The mechanism of chemical cracking and the rôle of hydrogen in steels are also covered, and the closing paper discusses laboratory techniques for the investigation of stress-corrosion cracking.

Short notes are given below to indicate the scope of the two papers dealing with austenitic chromium-nickel steels.

T. P. HOAR: 'Stress-Corrosion Cracking of Austenitic Stainless Steels in Aqueous Chloride Solutions', pp. 107-25.

This paper summarizes some outstanding results of work done in the University of Cambridge, from 1951 onwards. Tests were made on thin wire specimens of 18-8 chromium-nickel steel which, loaded under tension, were exposed to hot concentrated aqueous magnesium-chloride solution (usually 42 per cent. by weight). The apparatus used in the tests is illustrated. Among the aspects of the subject which have been studied are the change of electrode potential and mechanical properties of the specimens with time, the influence of variation in applied stress, the effect of temperature, the influence of the composition of the steels (within the '18-8' type), and the effect of physical condition (softened, pre-strained and refrigerated wires).

The results of these tests indicate the existence of two successive stages in the phenomenon of fracture of these steels by stress-corrosion cracking: (1) the induction period, during which electrochemical reactions leading to corrosion occur, but in which there is substantially no mechanical damage, although at the end of this period cracks are initiated: (2) propagation of the cracks. The effects occurring during these two stages are briefly discussed.

The second part of the paper reports further (electrochemical) experiments and deals with the possibility of prevention of stress-corrosion cracking by cathodic protection. The results are consistent with the mechanism proposed as a result of the first series of tests.

In conclusion, the mechanism of stress-corrosion cracking in 18-8 steels is compared with that occurring in aluminium-base alloys. Points of practical interest with regard to the large-scale use of austenitic steels are briefly reviewed.

C. EDELEANU: 'The Phenomena of Stress-Corrosion Cracking in Austenitic Stainless Steels', pp. 126-39.

Consideration of the various types of cracking which are liable to occur in high-chromium and in austenitic chromium-nickel stainless steels. It is shown that with all grades of stainless steel rapid stress-corrosion cracking can occur under certain corrosive conditions. In all grades there is a possibility of intercrystalline corrosion, but this can be prevented either by control of composition or by heat-treatment. Austenitic or predominantly austenitic steels may also fail by transcrystalline cracking, a type of stress-corrosion cracking which is not significantly affected by minor changes in composition nor, except under special circumstances, by heat-treatment.

It is assumed that in austenitic steels there is a path of easy corrosion across the grains. The nature of this path is not completely clear: in certain cases it may be strain-induced martensite, but this is not universally the case.

It is suggested that in chloride solutions localization of corrosion, which is believed to be a pre-requisite for stress-corrosion cracking, is due to the autocatalytic nature of the anodic reaction. A mechanism which will explain similar phenomena observed in caustic solutions is still awaited and it may prove that neither a highly localized corrosion path nor rapid local corrosion along the path is always essential for stress-corrosion cracking.

The propagation of cracks may in some cases be so rapid that corrosion cannot account for the rate of penetration in terms of metal removed: it is therefore suggested that the function of corrosion may be to 'trigger' the mechanical process which causes cracking.

Resistance of Austenitic Steels to Acids

W. MACHU and M. G. FOUAD: 'The Corrosion of a Stainless Steel containing 13 per cent. of Chromium and 8 per cent. of Nickel, in Acids and Acid Mixtures.'
Archiv f.d. Eisenhüttenwesen, 1957, vol. 28, Mar., pp. 157–65.

The behaviour of high-chromium and of austenitic steels in acid media is outlined in general terms, as an introduction to a detailed report of experimental work planned to determine:

1. To what extent the resistance of chromium-nickel steels to dilute mineral acids can be improved by inhibitors.

2. Whether the attack imposed by mixed acids is in accordance with the additive effect of the attack of the individual component acids.

3. Whether organic and inorganic inhibitors behave similarly or have different effects.

4. Whether the use of a combination of inorganic and organic inhibitors is beneficial or deleterious.

5. Whether inhibitors have a similar effect in all acids.

Tests were made in hydrochloric, sulphuric and phosphoric acid solutions and in mixtures of the three acids: with both the single and the mixed acids various concentrations were used. Three groups of inhibitors were employed: (1) potassium bichromate, (2) stannous sulphate or stannous chloride, and (3) organic inhibitors such as formaldehyde, quinoline and glue. (The mechanism of inhibition by such substances is briefly noted.)

The steel used was a low-chromium type, of the following composition: carbon 0·12, silicon 0·5, manganese 0·4, sulphur 0·03, phosphorus 0·03, chromium 13·2, nickel 8·8, per cent., tested in the form of polished sheet. The specimens were separately exposed, under full-immersion conditions, at room temperature, for 14 days. They were removed daily, washed, dried, weighed, and replaced. If the acid showed a high degree of metal contamination the beakers were re-filled with fresh acid solution.

The results of the tests thus made, on only one steel but in a wide range of conditions, are presented *in extenso*. Among the main conclusions drawn from the observations made are the following:

Mixtures of acids do not exert a purely additive effect, but behave as a complex acid mixture producing a degree of corrosion which is related to the activity of the hydrogen ions present. Phosphoric acid is capable of producing a protective layer on the steel, but in mixed acid solutions of which phosphoric acid is a constituent its inhibiting influence becomes operative only when it is present in substantial proportions.

Organic and inorganic inhibiting media vary in their action according to the acid to which they are added. In hydrochloric acid potassium bichromate intensifies corrosion, whereas in sulphuric acid it has a completely inhibiting effect. This inhibitor also increases the corrosive attack in mixtures of hydrochloric and sulphuric acids, but its adverse effect is nullified by the presence of quinoline or stannous sulphate. Phosphate ions lessen the protective effect of quinoline and stannous sulphate.

Two clearly defined factors affect attack by acid corrodents: the possibility of discharge of hydrogen ions and the capacity for formation or dissolution of protective films. Mixtures of different types of inhibitor may have an intensifying or a preventive influence: their effect, in many cases, increases with the concentration of the acid medium and the prolongation of exposure. The protection conferred appears to be the same whether the film formed consists of organic or inorganic material.

Constructional Materials for Use in Petroleum Refineries

J. F. MASON: 'The Selection of Materials for Some Petroleum Refinery Applications.'
Reprint of paper from *Corrosion*, May 1956; see abstract in *Nickel Bulletin* 1956, vol. 29, No. 7, p. 148.
Issued by INTERNATIONAL NICKEL CO., INC.; 8 pp.

Stainless-Steel Cloth for Filtering Plutonium Compounds

R. W. WIRTA: 'Corrosion of Type 316 Stainless-Steel Filter Cloth.'
General Electric Co. Report HW/31744, May 4, 1954; declassified 1956; 6 pp.

Filter sticks incorporating sintered molybdenum-containing austenitic nickel-chromium steel were severely corroded when used to handle plutonium-oxalate and plutonium-peroxide precipitates. Satisfactory service life is, however, being obtained from twilled Dutch filter cloth woven from 0·0023-in. diameter stainless-steel wire.

Stainless Steel for Use in Bone Fixation

W. H. CATER and J. H. HICKS: 'The Recent History of Corrosion in Metal used for Internal Fixation.'
Lancet, 1956, vol. 271, Oct. 27, pp. 871–3.

The paper reports an investigation of corrosion in stainless steel used for repair of fractures by plate insertion.

The cause of the trouble was traced to the substitution (unknown to the surgeons using the material) of another grade of stainless steel instead of the 18-8-Mo chromium-nickel type conforming to B.S. specification En 58J, which had been proved to be suitable for internal fixation work. Evidence collected from a large number of hospitals, in many parts of the world, confirmed failure of repairs made with the substitute steel.

The authors of this report, who are, respectively Senior Theatre Technician and Surgeon at a large accident hospital, urge that orthopaedic surgeons should realize the importance of using only the suitable type of stainless steel and that orders for material to be used for repair of bone fractures should, in all cases, specify the composition required. It is recommended that, in the light of modern knowledge, only stainless steel of the approved type or Vitallium (Vinertia), a cobalt-base alloy, should be used for internal bone repair.

Effective measures have been taken to recover and withdraw from circulation all screws or other parts made from the unsuitable steel.

Protection of Offshore Structures by Monel Sheathing

B. B. MORTON: 'Splash Zone Protection for Offshore Structures.'
Reprint from *World Oil*, Jan. 1957; 4 pp.
Issued by INTERNATIONAL NICKEL CO., INC.

Extension, some years ago, of oil-drilling operations into offshore locations led immediately to the problem of salt-water corrosion of steel piling and other parts of the plant used. A study of the type of attack involved at various levels demonstrated that corrosion is most severe in the splash zone, i.e., the area just above mean-tide level, which is intermittently wetted by tides, swells and sprays. (A chart, developed in the early stages of research, shows the intensity of corrosion experienced at various levels.)

In the intervening years Monel sheathing has proved to be a particularly effective shield for protection of steel piling and other parts in the critical zone. In addition to giving the required resistance to corrosion, this material has the ductility, strength and other mechanical properties necessary to withstand the impact and abrasion resulting from contact with marine vessels, tenders, mooring lines, etc. This article reviews experience of the satisfactory behaviour of Monel sheathing in five typical installations, dating from 1949 onwards. The reports amply demonstrate the adequacy of this form of protection, and it is noted that in view of the successful results already achieved there is a tendency among the oil companies to apply sheathing as a routine safety measure before setting new platforms in the water. On installations of early date the sheet used for sheathing in the splash zone was 0·062-in. thick, but it has been found that except where there is need for unusual resistance to mechanical damage a lighter gauge (0·050 in.) is satisfactory. In the interests of economy some work has been done also on even thinner-gauge material.

Welding continues to be the preferred means of attaching the protective covering to the steel tubular members, but other methods have also been studied. The author makes some recommendations with regard to the respective procedures which may be used. The article is well illustrated with photographs of typical installations in which Monel sheathing is employed.

Monel in Sewage Plant

INTERNATIONAL NICKEL CO., INC.: 'Monel Expansion Joints and Water Stops in Sewage-Treatment Plants.'
Reprint from *Public Works*, Aug., 1956.
Published Oct., 1956; 3 pp.

One of the large sewage-treatment plants operated by the New York City authorities is being enlarged to handle 120 million gallons of sewage per day, i.e., its capacity is being trebled. A total of about 55,000 lb. (25 tons) of 0·025-in. Monel sheet will be used for water stops for expansion and construction joints in the sedimentation, aeration, sludge-digestion and other tanks. The high tensile strength of the alloy, combined with its well-known resistance to corrosion, has led to its selection for this installation, and Monel sheet has the further advantage that its expansion and contraction characteristics are closely similar to those of concrete, thus lessening danger of cracking or other damage during extreme changes of temperature. The form of the stops and joints and the method of erection are illustrated in this article. The material used is supplied to A.S.T.M. specification B.127-49T. (Corresponding Federal Specifications are MIL-N-894C (Navy) or QQ-N-281a.)

Nickel-Molybdenum Alloys in Ammonia Deacidifier

G. WAHRBURG: 'Corrosion-Resisting Alloys in Coal By-Product Plant.'
Werkstoffe und Korrosion, 1957, vol. 7, Mar., pp. 132–3.

The article reports the satisfactory service being obtained from Hastelloy C (nickel-molybdenum-base alloy containing chromium and tungsten) in an ammonia-deacidifier unit of a coal by-product plant in Germany. Whereas units built from other materials had required replacement after very short periods, resulting in severe drop in production, the Hastelloy deacidifier has been operating since October 1955 without trouble. As a precaution, it was taken out of service after six months, for examination, but there was no evidence of any type of corrosion, or of damage by erosion, and the condition of the surface was such that the original grinding marks were still visible. A highly satisfactory working life is anticipated, and the experience with Hastelloy C in this application has led to its adoption for other components in the plant.

Base-Metal Hot Cracking in Welded Stainless Steels

P. P. PUZAK and H. RISCHALL: 'Further Studies on Stainless-Steel Hot Cracking.'
Welding Jnl., 1957, vol. 36, Feb., pp. 57s–61s.

Although hot cracking in austenitic-steel weld-metal has been alleviated to a large extent by the very general practice of specifying the use of compositions adjusted to give a small amount of ferrite in the weld deposit, such modification has not solved the problem of sporadic hot cracking in the basis metal of welded niobium-stabilized chromium-nickel steels. Some characteristics of the cracks formed and the inconsistencies of their occurrence are discussed as an introduction to this report.

Previous investigations of stainless steels, at the U.S. Naval Research Laboratory, had indicated that the presence of low-melting grain-boundary films was probably responsible for the hot cracking developed immediately after welding. Observations in the same laboratories had demonstrated the possibility of a stress-rupture type of propagation, at elevated temperatures, of low-ductility fractures originating at minute crack flaws which are developed by the liquation of grain boundaries during welding. Further work described in this paper was carried out to develop clearer information regarding the presence of liquation films, by determining the hot ductility of various types of stainless steel above and below the solidus temperatures.

The tests were made on niobium-stabilized (Type 347) steels, which have proved susceptible to base-metal cracking, and on straight chromium-nickel steel (Type 304) which has been shown to be immune from this defect. For detailed compositions of the steels used see table below:

	C %	Si %	Mn %	S %	P %	Cr %	Ni %	Mo %	Nb+Ta %	Cracking Susceptibility
low-C 347, high Nb	0·03	0·74	1·44	0·014	0·025	17·9	13·5	0·21	0·98	Most severe
low-C 347, low Nb	0·04	0·52	1·40	0·017	0·022	18·1	13·9	0·22	0·50	Severe
Std. 347	0·09	0·53	1·46	0·012	0·021	18·2	10·6	0·26	1·15	Borderline
Std. 304	0·09	0·52	1·01	0·024	0·027	18·8	9·7	0·30	0·12	None
Low-C 304	0·03	0·50	1·07	0·013	0·031	18·6	10·4	0·43	0·12	None

Tensile tests were made at various intervals over the range 2100° to 2600°F. (1150° to 1425°C.), demonstrating that in the straight chromium-nickel steels relatively high ductility and strength are maintained at all temperatures of test except 2550°F. (1400°C.), i.e., a point immediately above the bulk solidus temperature (2540°F.: 1393°C.). The behaviour of the niobium-stabilized steel was significantly different. Whereas in the Type 304 material nil-ductile fractures were obtained with extremely low loads (10–15 lbs.) only above the solidus temperature, fractures of this type were obtained at equally low loads for the low-carbon, high-niobium Type 347 steel at about 2450°F. (1343°C.), i.e., approximately 100°F. (56°C.) below its bulk solidus temperature (2565°F.: 1407°C.).

On the remainder of the steels previously studied (see table) a limited number of tests were made to establish the temperature at which such materials displayed low-load, low-ductility ruptures which could be ascribed to the liquation of grain-boundary areas.

The fracture surfaces exhibited by all the materials which, broken at temperatures above their solidus, developed low-ductility low-load fractures were identical in appearance: they were typically intergranular and dendritic fractures, characteristic of rupture by grain-boundary paths. The presence of grain-boundary liquation was clearly evident in these specimens.

The test results thus clearly support previous deductions regarding the development of fusible, grain-boundary films, and demonstrate that these films are responsible for base-metal cracking in welded stainless steels of the types discussed.

The data conform to the liquation hypothesis developed in previous investigations on the hot-cracking (tearing) defects found in castings. Additional casting studies have demonstrated that the abrupt nature of the strength and ductility changes which occur at hot-cracking temperatures is a characteristic of this liquation process for all materials at their bulk solidus temperature and also at a 'depressed-solidus' temperature for materials which contain low-melting grain-boundary segregates, e.g., sulphides.

Chemical analysis and X-ray diffraction studies indicate that the segregate composition involved in liquation cracking of the Type 347 steels is probably a eutectic-type mixture of carbides and nitrides of niobium with minor amounts of manganese, silicon and iron.

Root-Pass Welds in Stainless Steel: Improved Design

L. C. LEMON and W. R. SMITH: 'Joint Design for Making Root-Pass Welds without Filler Metal.'
Welding Jnl., 1957, vol. 36, Mar., pp. 240–2.

Illustrated description of design and technique developed by General Electric Company, Atomic Power Equipment Department, for making root-pass welds by the inert-gas tungsten-arc process without the addition of filler metal. It is found that the method provides an economical means of making root-pass welds in piping of stainless steel, killed steel and aluminium. The resulting joints are claimed to satisfy all the requirements normally laid down for root passes.

Welding Problems in Atomic-Energy Plants

I. H. HOGG: 'Welding Techniques in Atomic-Energy Plants.'
Atomics and Nuclear Energy, 1957, vol. 8, Mar., pp. 77–82, 99.

The author discusses particular problems which concern the welding engineer in the construction of

atomic-energy plants, and describes some methods which have been adopted in installations operated by the U.K. Atomic Energy Authority.

The article is based on experience at three plants:

(1) Springfields, where uranium metal is extracted from the ore and bars, 'canned' in aluminium, are sent to Windscale.

(2) Windscale, where the uranium is irradiated and subsequently put through a chemical processing plant in which the plutonium is separated from the uranium and fission products.

(3) Capenhurst, where uranium hexafluoride manufactured by Springfields is passed through a gaseous diffusion plant which gives an enrichment of the U^{235} isotope.

Welding problems at Springfields were of a normal kind and some special difficulties arose at Capenhurst, but it was at Windscale that the major problems were encountered. On account of the radioactivity of the materials involved, the plant had to be shielded and, once placed in operation, could not be approached. It was therefore enclosed in large concrete cells, which were completely sealed before operation began. Since no maintenance could be carried out, the use of pumps and valves had to be avoided, and arrangement was on a vertical plan, so that gravity might be used to feed the liquors. A further complicating factor was that highly corrosive liquors would be handled and the corrosion-resistance of the constructional materials would therefore control the life of the plant.

After extensive tests, the material selected for large-scale use was a stainless steel containing chromium 18, nickel 13, niobium 1, per cent. and the composition of the welding electrode to be used on it was chosen to give, in the final deposit, a ferrite content of approximately 5 per cent. Steel found to satisfy this requirement contained chromium 18, nickel 9, niobium 1, per cent.

Methods of fabrication necessitated by the inaccessibility of some of the welds are described, with drawings of the joint designs, etc., and methods of inspection are detailed. The paper is illustrated with photographs of relevant parts of the respective plants.

Powder-Metallurgy Symposium

See abstract on p. 84.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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THAMES HOUSE · MILLBANK · LONDON, S.W.1

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WESTMINSTER, LONDON, S.W.1